CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-6873: True Road Surface Deflection Measuring Device (Phase 1)

Background

Surface pavement deflection measurements began more than 60 years ago with the development of the Benkelman Beam as part of the WASHO Road Test. Pavement engineers have always recognized the usefulness of pavement deflection data to evaluate and monitor pavement response (e.g., maximum deflection) and pavement structural conditions (e.g., backcalculation of layer moduli). The Texas Department of Transportation (TxDOT) is one of the leading agencies in using deflection data as well as developing and implementing devices to measure pavement deflections. Two recent examples of TxDOT-sponsored device development are the Rolling Dynamic Deflectometer (RDD) and the Total Pavement Acceptance Device (TPAD). While these two devices have extensively demonstrated their usefulness and capabilities, they do not measure pavement deflection under a standard axle load and they operate at low speeds. While they provide a deflection measure that can be used to assess pavement condition, it cannot be used for backcalculation of layer moduli and rehabilitation design.

This project's objective was to develop a sensor system capable of accurately measuring pavement deflection for project-level and network-level studies, which continuously moves along the pavement at a speed of at least 10 mph.

What the Researchers Did

The researchers investigated high performance lasers for monitoring the deflection caused by a truck driving on a road. The sensor system developed uses three distance measurement lasers: two lasers monitor the undeflected pavement surface, while the third monitors the deflection caused by the loaded truck axle. While the measurement lasers are highly accurate, no current technology can determine the absolute position of a system with respect to an inertial frame of reference; at least, with the required precision (i.e., 100 microns) and during the time required by both lasers to cover the deflection bowl. For example, assuming a truck velocity of 45 mph (20 m/s), the position of the lasers has to be known in an inertial frame of reference for at least 0.25 seconds, with 0.004 inch (0.1 mm) accuracy. These considerations mandated a physical coupling between sensors in order to reduce the degrees of freedom of the system, and the addition of other sensors to estimate such degrees of freedom.

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The simplest mechanical coupling, a rigid beam, allows only six degrees of freedom (i.e., three degrees in translation and three in rotation). In practice, changes in distances that do not exceed a fraction of the required accuracy could be tolerated (i.e., 100 microns). Thus, in creating this sensor system, the research team created a setup containing a beam suspended from a trailer, on which the distance-measuring lasers are attached as follows:

- One laser monitors the pavement away from the deflection bowl (head A).
- A secondary laser monitors the pavement immediately after the first laser to estimate the position of the beam with respect to the ground (head B).
- The third laser monitors the surface deflection (head C).

What They Found

The research team evaluated the accuracy of the resulting relative position measurement and computed the root mean square (RMS) error in the residuals between the first and third lasers to capture the uncertainty in the vertical axis. During field testing, the RMS error ranged from 80 to 100 microns. Since the RMS error measures the average dispersion of the measurements for each single point, it overestimates the error that can occur when averaging the altitude measurement over multiple points. If the distance measurement error is normally distributed, then the error reduced by the squared root of the number of points. Since 400 points are used to estimate one altitude, the actual error is on the order of 5 microns, which is well below our specifications. The positioning error related to the ring laser gyro is on the same order of magnitude, and the total measurement uncertainty would be on the order of 50 microns.

What This Means

This research project created a laser sensor system capable of capturing pavement deflections under a moving vehicle under different loads and speeds. The deflections match closely those captured by the reference device.

The surface deflection of a pavement structure is an important property that can be used to address many TxDOT needs: 1) measurement of road condition, 2) early indication of pavement deterioration, and 3) input for layer moduli backcalculation. Therefore, a system that can allow TxDOT to measure surface pavement deflections without the need to close the highway to traffic yields multiple benefits. For example, the Maintenance Division would be able to use this device to determine the condition of the pavement and use this information in Pavement Analyst to better manage the state's highway network and to make better informed maintenance and rehabilitation decisions. This information would directly support the 4-Year Plan. In addition, back-calculated layer moduli from surface deflections could be used by the Construction Division for more accurate rehabilitation design.

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Technical reports when published are available at
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